Characterization of fish assemblages within San Francisco Bay: implications for biological monitoring strategies and design of habitat restoration projects.

Rachel Lux, Abigail Warwas, and Holly Blalock-Herod, US. Fish & Wildlife Service, Stockton, CA 95205

ABSTRACT

The U.S. Fish & Wildlife Service, Stockton, California, juvenile fish monitoring program (JFMP) is a partner in the Interagency Ecological Program (IEP) and under the auspices of IEP, has intermittently collected data during an ongoing study in the San Francisco Bay area over the past 24 years as part of a combined effort to monitor juvenile fish abundance in the Bay, Estuary, Delta, and Sacramento and San Joaquin rivers. For the last seven years, the JFMP has regularly collected data on fish species richness and abundance from nine sample sites within San Pablo and Central San Francisco Bay (SPSFB). Here we provide a preliminary analysis of five fish assemblage metrics (species richness, diversity, similarity, stability, and persistence) that were examined between 1999 and 2005 for SPSFB and for each site. We also illustrate the utility and define limitations of incorporating JFMP data in ongoing and future restoration projects conducted by other agencies.

INTRODUCTION

Habitat restoration is a key concept when considering management of the San Francisco Bay and Estuary as roughly 80% of the natural tidal wetlands have now been lost (TBI 1998). The objectives of habitat restoration projects are varied, though many goals include improving form and function of wetlands and tidal areas, improving the quality of biological integrity in the estuary, and managing, preventing, reducing, or controlling non-native invasive species (Brown 2003a, Goals Project 1999). Block et al. (2001) discussed the general lack of monitoring information on community structures and wildlife populations collected before and after project completion which impedes determination of whether the restoration project met objectives and goals. While many organizations may not be able to conduct large-scale biological monitoring before and after restoration, other programs already exist that regularly collect biological and physical data that may be appropriate for some monitoring needs for a given project.

For example, as an IEP project, the JFMP has conducted long term monitoring throughout the San Francisco Bay and Estuary, including seven years of consistent sampling at nine sites on both the East and West sides of SPSFB) (Figure 1). Data for each site can be analyzed as an example of control sites against which restoration sites can be compared, or can provide sites to test restoration theory in light of historical fish assemblage trends. Such long-term consistent data provides a valuable resource to compare species specific or fish assemblage response at sites before and after restoration projects (Block 2001).

Here we provide a brief examination of the JFMP fish assemblage data within SPSFB and at individual sites within SPSFB from August 1999- July 2005 to preliminarily characterize the fauna in terms of richness, diversity, similarity, stability, and persistence. Assemblage metrics were selected since many restoration goals are broad and typically cover improving conditions for a variety of species. (Individual fish species data are available but are not examined in this analysis). Within an existing framework for monitoring habitat restoration projects (See Block et al., 2001), we describe where JFMP long-term fish assemblage data can be incorporated into Before-After-Control-Impact (BACI) monitoring designs. We also describe the limitations and benefits of integrating these data to facilitate biological evaluation of habitat restoration.

Figure 1. San Francisco Bay area with JFMP sites (●). Map courtesy of Larry R. Brown, USGS.

Topsmelt captured at China Beach.

METHODS & RESULTS

All sites were sampled bimonthly following JFMP standard operating procedures (USFWS, 2005). Fish data were assembled through queries of the JFMP historical database and were limited to the nine sample sites from sample years 1999-2005. Fish not identified to species were excluded. JFMP sampling gear is targeted towards juvenile and small adult fish; therefore, incidentally captured large fish species (i.e. leopard shark) were excluded from the analysis. Since overall assemblage improvement is generally a target for restoration we chose assemblage metrics that allow for inevitable sampling variation (due to changes in site physical parameters, weather conditions, etc.) to conduct our baseline analysis. To characterize the fauna we selected the following metrics: species richness, diversity (Simpson's Index), similarity (Morisita's Index), stability (Kendall's Coefficient of Concordance, corrected for ties), and persistence (Index of persistence). Each metric is explained below in the corresponding graphs and results. All diversity calculations and Morisita's Index were completed using Programs for Ecological Methodology software (Krebs 2003). Kendall's W_c and Index of Persistence were calculated in Microsoft Excel®.

SPECIES RICHNESS

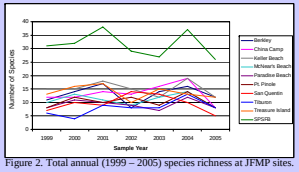

Figure 2. Total annual (1999 – 2005) species richness at JFMP sites.

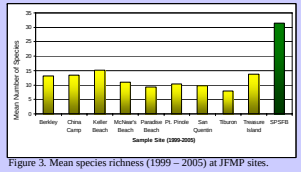

Figure 3. Mean species richness (1999 – 2005) at JFMP sites.

Species Richness for SPSFB within a year (Fig. 2) ranged from 26 to 38 species ($\bar{x}$ = 31) between 1999 and 2005. No single site ever reached the total species richness detected within SPSFB. The greatest number of species (19), were found at both China Camp and Keller Beach in 2004 and the least number of species (4) were detected at Tiburon in 2000. Mean species richness at individual sites between 1999 and 2005 was greatest at Keller Beach, China Camp, Berkley, and Treasure Island (Fig. 3).

DIVERSITY

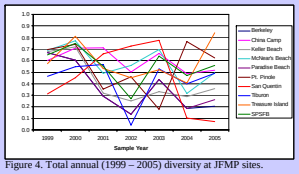

Figure 4. Total annual (1999 – 2005) diversity at JFMP sites.

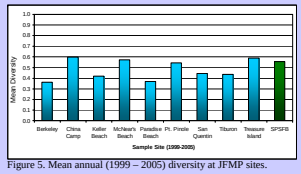

Figure 5. Mean annual (1999 – 2005) diversity at JFMP sites.

Diversity was measured using Simpson's Index which ranges from 0 (low diversity) to 1 (high diversity) and is sensitive to changes among the more abundant species (Krebs, 2002). Total diversity for SPSFB (Fig. 4.) was low to moderate and ranged from 0.27 to 0.75 ($\bar{x}$ = 0.55). Maximum diversity for any single site was at Treasure Island in 2005 (0.84), while minimum diversity was 0.04 at Tiburon in 2002. Mean diversity at individual sites between 1999 and 2005 was low to moderate, with China Camp, McNear's Beach, Pt. Pinole, and Treasure Island exhibiting the greatest diversity (Fig. 5) and all but Pt. Pinole having a greater mean diversity than SPSFB.

SIMILARITY

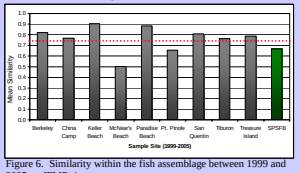

Figure 6. Similarity within the fish assemblage between 1999 and 2005 at JFMP sites.

We used Morisita's Index to evaluate similarity of the fish assemblage over time within a site. Morisita's Index is considered independent of sample size and ranges from 0 (no similarity) to 1.0 (complete similarity). Mean similarity within a site over time was high (>0.75) for all but two sites (McNear's Beach (0.5) and Pt. Pinole (0.65) and SPSFB (0.67) (Fig. 6).

PERSISTENCE

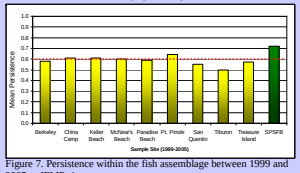

Figure 7. Persistence within the fish assemblage between 1999 and 2005 at JFMP sites.

Persistence (PR) is the continued presence of species with respect to disturbance (Connell and Sousa 1983). The Index of PR ranges from 0 (no persistence) to 1 (complete persistence), where assemblages >0.6 are considered persistent (Meffe and Minckley 1987). PR in was detected for SPSFB (0.72), China Camp (0.61), Keller Beach (0.61), McNear's Beach (0.60), and Pt. Pinole (0.64) (Fig. 7).

Preparing to beach seine at San Quentin.

STABILITY

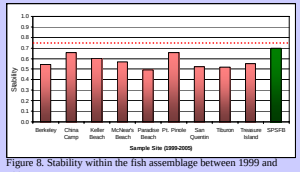

Figure 8. Stability within the fish assemblage between 1999 and 2005 at JFMP sites.

Natural communities are assumed to be inherently stable meaning there is a relative constancy of species abundances over time despite disturbances (Connell and Sousa 1983). Stability was measured as Kendall's coefficient of concordance (Wc) (with corrections for ties) as outlined in Zar (1999). Wc is a nonparametric statistic that measures association among more than two variables (multiple years) to examine assemblage stability. We incorporated all species collected, not just the abundant species as recommended by Grossman et al. (1990). Wc ranges from 0 (no association) to 1 (complete association) where complete association indicates that if a species was common in one year it will generally be common in all years examined. Scores greater than 0.75 are considered high (Grossman et al. 1990). SPSFB (0.70) and all sites had moderate stability in the abundance of fish assemblage members (Fig. 8). China Camp and Pt. Pinole had the greatest stability (0.65) while Paradise Beach had the lowest stability (0.49).

MONITORING FRAMEWORK

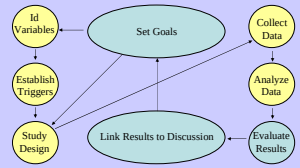

Figure 9. Flow diagram outlining monitoring steps modified from Block et al. (2001). Yellow circles indicate where JFMP methods and data can be used to improve habitat restoration monitoring.

TAKE HOME POINTS

- The JFMP has regular and consistent fishery data from San Pablo and San Francisco Bays, the Sacramento and San Joaquin rivers and delta.
- Fishery data for sites within SPSFB may be useful as "control" sites to determine if assemblage change at a habitat restoration site is due to natural events or treatment effects.
- These sites may also be good candidates for pilot restoration projects to test restoration techniques or to examine effects of habitat restoration on the fish assemblage.

DISCUSSION

In a preliminary characterization, based on JFMP data, the SPSFB fish assemblage was found to have greater species richness than any single site examined in this study. Mean diversity within the SPSFB was moderate while individual sites ranged from low to moderate diversity. Similarity within the fish assemblage over time was high for several individual sites and moderate within the SPSFB. The SPSFB and most individual sites exhibited moderate stability. SPSFB and all but two individual sites were considered to have a persistent fish assemblage. These data indicate that at this broad spatial and temporal scale that this fish assemblage within SPSFB and at individual sites is somewhat consistent over time given the different kinds of disturbances that fluctuate at this scale (weather, flow, temperature, salinity, tidal cycles, etc.). At Tiburon, for example, the area sampled at low tide is a mud flat, whereas at high tide the sampled area is largely vegetation. Other such considerations include, but are not limited to, seasonal variations within a site due to the presence/absence of macroalgae, temperature fluctuations, and salinity variation. When these data are examined at different spatial and temporal scale, it is possible that these metrics may increase or may become more predictable when correlated with differing environmental variables. Consistency within these metrics may allow these sites to be considered useful as "control" sites to assist with distinguishing change at a restoration site due to natural events versus treatment effects. Sites that are still found to have lower values may be good candidates for pilot restoration projects to test restoration techniques or determine how to better predict habitat restoration affects to the fish assemblage.

In the broad framework of a monitoring program (Fig. 9), JFMP monitoring data could be a useful resource. When the goals of a habitat restoration project include improving a fishery resource, one appropriate measure of restoration success would include fish species or fish assemblage response. IEP projects, including the JFMP, have collected a variety of fishery and physical data within SPSFB over irregular intervals from the 1970s through the 1990s. California Department of Fish and Game consistently collected fishery data from the Bay during the early to mid 1980s. JFMP began regularly monitoring the fishery assemblage in 1999. Once the variables to measure response (species or assemblage) have been identified then thresholds and triggers to document when change has occurred can be set. The JFMP sample sites can be examined at different spatial and temporal scales to correlate how differing environmental variables affect fish assemblage metrics. Thresholds for success could be set based on these background fluctuations that occur due to existing phenomena occurring at sites within SPSFB.

For the JFMP data from SPSFB to be most applicable to cooperators conducting a habitat restoration and monitoring, their monitoring strategy would need to be established as a "quasi-experiment" (See Block et al. 2001 for discussion) in a BACI design incorporating JFMP fish sampling methods at restoration sites and using JFMP sites as control sites. Partners incorporating the JFMP data should consider the limitations of the data. JFMP data are collected from a small number of sample sites within SPSFB. These sites have a narrow range of macro- (tidal flats, shallow bay channel) and micro-habitat types (vegetated or open, sand or cobble substrates). Additionally, JFMP collection methods exhibit gear selectivity; however, the JFMP data could still prove extremely useful in habitat restoration applications. JFMP data are, as previously mentioned, collected consistently and raw data are public domain (http://bdat.ca.gov/). Multiple species or assemblages can be examined allowing restoration targets to be set as broad or specific as desired for individual projects. These data can be examined over many temporal and spatial scales, and could be correlated with other environmental parameters (flow, salinity, temperature, etc.) to further refine variables and gain insight into habitat restoration.

Literature Cited is available upon request.

ACKNOWLEDGEMENTS

We would like to thank the JFMP crew and data management team for their diligent efforts while collecting and entering these data so they are available for all interested parties to use. We would also like to thank all of the reviewers who provided constructive comments to improve this poster.

Seasonal algae at Keller Beach.